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CONCERNING

SCIENTIFIC ASSESSMENTS OF THE IMPACTS OF GLOBAL CLIMATE CHANGE ON WILDFIRE ACTIVITY IN THE UNITED STATES

Mr. Chairman and members of the Committee, thank you for the opportunity to talk with you today about the interactions of climate change and wildfire. I will give you a brief description of the Forest Service research programs in climate change and wildfire. I am accompanied today by Dr. Susan Conard, our scientist who leads the national fire ecology research program, and she will discuss the science of the interactions between climate change and wildfire.

The Earth's climate is changing and will continue to change for many decades. Decisions being made today by policymakers and public and private sector resource managers will have implications through the next century. Forest Service Research and Development provides long-term research, scientific information, and tools that can be used by managers and policymakers to address climate change impacts to forests and rangelands.

Forest Service climate change research priorities involve three areas: adaptation (increase forest stress resilience); mitigation (increasing carbon sequestration through storage in soils, living plants and wood products); and decision support for practioners and policymakers.   To do this, we maintain an extensive infrastructure of research laboratories, long-term research studies, and continuous data from nationwide forest surveys and experimental forests. Several long-term data sets - the Nation's Forest Census (Forest Inventory and Analysis) and the Experimental Forests – provide several decades worth of information on forest and rangeland trends.   Over two decades of focused climate change research, three decades of air pollution research, and long experience with scientific assessments provide a firm foundation for addressing climate change and forest management. The Forest Service climate change research program is supported by strengths of its more traditional research in areas such as ecophysiology, landscape ecology, watershed hydrology, vegetation modeling, nutrient cycling, and forest management. Further support comes from partnerships with universities, federal and state agencies, non-governental organizations, and the forest industry here and abroad.

Scientists from the Forest Service are active in the United States Climate Change Science Program (CCSP) and participate in CCSP and Intergovernmental Panel on Climate Change (IPCC) assessment activities. In addition, the Forest Service climate change research, fire ecology, wildland fire, and fuels research programs combine to provide a rich source of information, data, and scientific discoveries. The science is essential to underpin predictive models and adaptation and mitigation techniques. Important aspects of the research are the effects of fire on carbon storage, atmospheric chemistry and warming potential, water supply, and ecosystem health and resiliency. Forest Service scientists and colleagues funded by the National Fire Plan and the Joint Fire Science program - managed jointly by the Forest Service, US Geological Survey, Bureau of Land Management, National Park Service, US Fish and Wildlife Service, and the Bureau of Indian Affairs - are studying wildfire and climate interactions, predicting and monitoring wildfire emissions, and looking at factors that affect fire behavior and fuel consumption. This research allows us to better understand fire and water supply issues, perhaps two of the most critical issues for western states.

I would like to say a few words about the scientific process. Science can describe the connections between human and ecological systems, develop methods to forecast the occurrence of damaging fire events and other disturbances, and characterize the possible outcomes of alternative management options. Scientists can help managers interpret what they are seeing on the ground and can help evaluate the environmental effects, social and economic costs and benefits, and effectiveness of potential management programs towards reaching management objectives. This scientific information can help managers and policymakers to decide the most appropriate management strategies for specific situations.

As scientists, we know that the scientific basis for understanding fire and climate change interactions is more complete for some interactions than for others. We have important knowledge gaps that we must address. For example, current estimates of fire emissions vary widely. While we have information for a few systems, we do not have good information broadly on burn severity or on how burn severity will cause emissions to fluctuate. We also do not know how much we can increase carbon storage without causing unacceptable increases in fire hazard in fire- dominated ecosystems.

The interaction of climate change in with ecosystems is also the subject of the Synthesis and Assessment Report (SAP) 4.3, *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity*, is one of 21 synthesis and assessment products being produced by the CCSP. These reports summarize scientific understanding of various aspects of climate change for government and private sector decision-makers. USDA participates in CCSP and is the lead agency for SAP 4.3. The direct and indirect climate effects on wildfires is one topic addressed by SAP 4.3, and when the report is finalized, will help to provide the necessary scientific basis for assisting decision and policy makers.

As we continue to integrate results from various scientific studies, we increase our understanding of where and why results differ, as well as where results can be generalized. Scientists' ability to provide this kind of information will aid decision-makers.

Although policy questions may often be framed as science questions, many non-scientific considerations must be part of the answer to these policy questions. While science can provide a foundation for management and policy decisions, science alone is not sufficient to determine policy. Adaptive management by land managers is a useful tool that combines emerging research with evaluation of management practices. This approach enables managers to modify practices as our understanding of management impacts improves. This is an important concept in dealing with active application of science by practitioners and policymakers.

While we still have much to learn about the interactions among climate change, carbon emissions, and wildfire, there are science-based adaptive management approaches we are taking today that can help reduce the impact of wildfires on climate change and mitigate the impacts of climate change on our nation's forest and grasslands. For example, the Forest Service has increased our fuel reduction work over the past several years, which reduces the threat of large wildfires and may increase resilience of forests to the effects of climate change.

Mr. Chairman, Dr. Susan Conard will now address in greater detail the science of the interactions between climate change and wildfire activity. Following her testimony and my concluding remarks, we would be happy to answer any questions you might have.

Scientific Research on the Impacts of Climate Change on Wildfire Activity

Mr. Chairman and Members of the Committee, thank you for the opportunity to discuss with you today what scientific research tells us about the potential interplay of climate change and wildfire. Today I will talk about the current scientific understanding of historical interactions of climate and wildfire, how climate is changing fire regimes, how wildfire affects climate change, some of the research-based knowledge and tools being developed that help us understand how climate change is likely to affect wildfires, and ways in which this knowledge can help support managers and policymakers.

Background

A number of recent scientific studies indicate that variations in cyclic weather patterns and climate over time are factors in the increase in large, severe fires and how fire patterns change from year to year. According to data from the National Interagency Fire Center (NIFC), annual burned areas have exceeded 7 million acres only 7 times since 1960; 6 of those have been in the past twenty years NIFC. One possible outcome of climate change is an increase in the incidence and severity of wildland fire in some parts of the continent and in Alaska. Fuel treatments and active forest management have reduced fire hazard and can help to mitigate these increases in fire hazard

Recent data and projections from the Intergovernmental Panel on Climate Change (IPCC) provide some context for this discussion. IPCC reports (IPCC 2007) show that there have been clear patterns of temperature increase and long-term trends in precipitation change around the world since 1900. Results from over 20 different global models project strongly increasing temperatures for much of the globe, with the greatest increases generally projected for northern latitudes. For North America the greatest increases in winter temperatures are in the boreal and arctic zones, with summer temperature increases the greatest across the lower 48 states in the United States. Precipitation is projected to decrease in the southwestern United States, and increase in some areas of the northeast. We can expect these temperature and precipitation patterns to lead to longer and more severe fire seasons in many areas of the United States and Canada, which underscores the need to continue to engage in active forest management as a mitigation measure.

Historical Wildfire

Natural disturbance—whether by fire, insects, disease, hurricanes, ice storms, floods, or tornadoes—is a fact of life for all ecosystems. For most forests and rangelands, fire is a relatively regular occurrence, although the typical frequency, behavior, and severity of the fires (the fire regime) vary greatly from one forest type to another. This difference in fire regimes is a function of the combination of weather, topography, stand structure (fuels), and occurrence of ignitions that characterize specific ecosystems (e.g. Pyne et al. 1996). For example, many prairies and grasslands historically burned every few years, or even annually. Dry pine forests burned primarily in frequent, low intensity surface fires. Cool, moist conifer forests, such as coastal Douglas-fir in the Pacific Northwest of the United States have burned in high intensity stand replacement fires only every few hundred years (Heinselman 1978, Heyerdahl et al. 2001, Leenhouts 1998, Schmidt et al. 2002). While each ecosystem has a typical fire regime, the characteristics of individual fires may vary widely as a function of specific fuel structure, weather conditions during the fire, and weather and climate patterns in the weeks (and even years) before a fire occurs (Leenhouts 1998, White et al. 1996).

In forest systems, the highest severity fires (where severity refers to the level of ecological impact) are in fire regimes with stand replacing fires, which typically kill all or most of the living vegetation, and burn deeply into surface litter and duff layers. Ecosystem recovery is generally slow (100 to 300 years) as is the return to pre-fire levels of fuel loadings and fire frequency. In some forest and shrub systems, as well as in perennial grasslands and savannas, fires may top-kill most of the above-ground biomass, but native species are adapted to recover through re-growth from live roots, basal sprouting or regeneration from seed. Such systems recover rapidly—and typically undergo shorter interval between fires.

The lowest severity fires in forest systems burn only surface fuels and low-growing vegetation, and have little impact on overstory trees. These surface fire regimes are most typical of forest types on dry sites or with fairly open canopies, and with grassy or shrubby understories, such as ponderosa pine and loblolly pine. Such surface fires typically occur much more frequently (every 3 to 30 years) than stand replacement fires.

In mixed severity fire regimes, there may be a pattern of relatively frequent surface fires, with less frequent stand replacement fires, or patches of high fire severity, that are a function of either unusually severe weather or reduced fire frequency that leads to greater than normal fuel accumulation. This appears to be the pattern in many conifer forests in the west and can also occur in some of the Southeast.

In some systems in North America (such as ponderosa pine and loblolly pine forests which historically had high frequency, low severity fires) reduced fire frequency beginning in the late 19th century has led to substantial fuel accumulation. These fuels increase fire hazard and burn severity, a condition that can be exacerbated by a warming climate and longer fire seasons (e.g Westerling et al, 2006).

Effects of Climate on Fire Regimes

While climate has always been variable, the suite of climate models evaluated by IPCC project an increased frequency and intensity of drought and high-intensity rainfall events, particularly in the boreal and temperate zones of the northern hemisphere. These predictions take into consideration the larger land mass in the northern hemisphere as compared to the southern hemisphere. The largest changes in temperature are projected for high latitudes in both the northern and southern hemispheres; however, .water has a moderating effect on changes in temperature and precipitation; hence the northern hemisphere, with its relatively larger land mass, will likely see more frequent and intense weather patterns (IPCC 2007.

Historically, the extent and severity of drought, timing of spring snowmelt, and changes in ocean circulation patterns have all correlated with the extent and severity of wildfire on forests and rangelands. The impacts of climate change may be most noticeable in the short-term on fire regimes typified by low or mixed severity fires because fuel structure in these systems reacts more rapidly to fire exclusion and drought is more frequent.

Warmer winters also exacerbate summer drought because of reductions in winter snow pack depth and duration that alter both the timing and volume of runoff, leading to longer summer droughts, larger water deficits, and more severe fire seasons (e.g. Westerling et al. 2006). Wet years of climatic cycles lead to high rates of vegetative growth (fuel production), often in the forest understory. Drought stresses trees and other vegetation, causing increased flammability of live and dead fuels and increased susceptibility to a number of insects (most notably bark beetles) and some pathogens. Warmer winter temperatures can increase the reproductive rates of insects, resulting in a second generation in one year. In addition, warmer temperatures can extend the ranges of some insect populations, as has happened with the mountain pine beetle in the western United States (Logan et al, 2003). Recent research shows clear relationships between warmer temperatures and drought on extensive insect outbreaks in southwestern forests and Alaska.

A number of studies published over the past two decades suggest that a warming climate will cause increases in fire hazard, likely leading to increases in the annual area burned as well as in the severity of fires (Brown and Smith 2000, Flannigan et al. 1998, Fosberg et al 1996, Lenihan et al. 1998, Stocks et al. 1998, Wotton and Flannigan 1993). These studies in general do not take into account mitigating measures such as fuel reduction. These projections are supported by numerous studies that relate inter-annual or multi-year changes in fire patterns to regional patterns of climate variability (e.g. Swetnam and Betancourt 1990, 1998; Fauria and Johnson 2006; Kitzberger et al. 2007; Murdiyarso and Adiningsih, 2007; Swetnam and Baisan 1996; Westerling et al 2006).

As climate warms and becomes more variable, some of the greatest effects on fire regimes are expected to occur in the boreal zones of North America (primarily Alaska and Canada) and in Eurasia (Fosberg et al. 1998, Flannigan et al. 1998, Fauria and Johnson 2006). The effects of climate on fire regimes in systems with deep organic layers such as peat bogs, are predicted to be large but are poorly understood (Morrisey et al 2000, Turetsky et al. 2006). This is tremendously important because of the large carbon stores that can be released from these ecosystems if fire frequency and the depth of burn increase.

In recent years, we have seen particularly severe periodic seasonal droughts in the western United States, Alaska, and Florida. Not coincidentally, these regions have accounted for a majority of increased wildfire activity in the United States. Climate models, which I will speak more of later, project increased drought in the southwest United States. The same models project increased rainfall in the upper Midwest, Great Lakes and New England.

Changes in fire regimes and in wildfire occurrence and severity have implications for atmospheric chemistry, the influence of smoke on air quality, the quality of our drinking water, and the ability of forests and grasslands to store carbon. These changes could both facilitate and force changes in the structure and composition of ecosystems, with feedback loops that are largely unknown. Ultimately, changes in fire regime can be expected to result in substantial alterations to the geographic distribution of trees, other plant species, and animals (e.g. Heinselman 1978).

Circulation Patterns and Wildfires

The severity of fire seasons in different parts of North America has been shown to be highly correlated with annual and multi-year weather patterns (such as those resulting from changes in El Niño, La Niña or other ocean circulation patterns). (e.g. Swetnam and Betancourt 1998, Kitzberger et al. 2007). In mountainous areas of the western United States, one of the key factors associated with severe fire seasons is the timing of snow melt in the spring, with earlier snow melt often being a precursor to longer summer drought periods (e.g. Westerling et al. 2006). High temperatures and low rainfall (or longer dry seasons) together produce increases in area burned and numbers of large, intense fires.

The El Niño-Southern Oscillation provides the south and southwestern United States with abundant winter rains every 3-7 years, supporting luxuriant growth of grasses and forbs the following growing season. If this season in turn is followed by drought, the abundant surface fuels increase the probability of stand-replacing fires to develop in open woodlands, parklands and dry pine (ponderosa) forests (Swetnam and Baisan, 1990). Recent research indicates that the warm phase of the Atlantic Multidecadal Oscillation has coincided with 40-60 year periods of increased fire frequencies throughout the western United States, and that the West appears to be entering such a period now (Kitzberger et al., 2007).

The effects of these multi-year weather patterns may well amplify climate change-induced effects to forests and grasslands. Seager et al (2007) recently projected severe drought conditions for much of the 21st century in the southwestern United States. This supports projections of multiple models for decreased summer rain and increased temperatures in this region (IPCC 2007).

Tools for Assessing Interactions between Climate Change and Wildfire

Scientists are developing and using a number of tools to assess the interaction of climate change and fire. Under a changing climate, fire occurrence and patterns of ecosystem recovery after a fire may also change, leading to changes in vegetation structure and composition and in the ability of those ecosystems to store carbon. Global General Circulation Models (GCMs) are used to project climate effects on temperature, precipitation and other factors and generally do not incorporate disturbances such as wildfire except in a very coarse way. Their predictions are primarily useful for long-range and large-scale (e.g. national or broad regional) thinking and planning. Even at a coarse scale, however, it is clear that the mechanisms and expected magnitude of impacts of changing climate will vary greatly across the country.

To develop landscape-scale projections of impacts of climate change on ecosystems or on fire that are useful for management and planning, scientists adjust General Circulation Model outputs for local variations in terrain, temperatures, precipitation, and vegetation. While Forest Service scientists are not generally involved in developing General Circulation Models (this being largely the realm of physicists and atmospheric chemists), they use General Circulation Model outputs to project changes in vegetation, fire hazard, wildlife habitat and water supply both at coarse scale and at scales more appropriate to local and regional resource management planning. Information from field studies and landscape-level models can also be used by General Circulation Model developers to help make their models more realistic, especially in terms of incorporating major landscape processes such as fire.

There are several types of vegetation models that are useful for assessing the potential interactions among climate change, vegetation, and wildfire. These range from global to regional or landscape-scale, and they take a range of approaches (See Keane et al. 2004 for an extended discussion). Some models are based on biogeochemical processes and focus on overall plant productivity in a given climate, but often without regard to the likely presence or absence of vegetation, or of individual species (e.g., Neilson et al, 2005). Other models use detailed knowledge about how individual species grow currently to project viability, and growth, and changes in species composition (Bugmann and Solomon, 2000; Busing et al, in press). Still other types of models evaluate current climatic limits of species or ecosystems and use that information to project areas where habitat may be suitable in the future (Iverson et al, 2004; Rehfeldt et al, 2006). Further, some of these models are landscape-level models (Mlandnoff and Liu, 2003) and others model individual stands and use statistical information on distribution of forest types to develop projections.

Models give us projections of species environmental potential but not actual capability to move on the landscape. Scientists are working hard to realistically represent vegetation change and species migration given that the capability of many long-lived plant species to migrate may be slower than the projected rate of change in distribution of suitable habitat (Neilson et al. 2005).

One example of a biogeochemical model that looks at fire, which is under development by Forest Service researchers, is the Mapped Atmosphere-Plant-Soil System. The MAPSS simulates potential impacts of changes in the physical environment on vegetation dynamics for major ecosystems (Bachelet et al. 2003). The fire module predicts substantial increases in burned area and emissions from wildfires, particularly in the boreal zones and in the western United States (e.g. Lenihan et al. 2003).

Keane et al. (2004) discuss and compare over 40 landscape fire models from around the world that are able to incorporate climate into their simulations. A number of landscape-scale models developed by Forest Service researchers and their collaborators predict large changes in fire regimes and vegetation patterns in areas as diverse as Glacier National Park, California, the Ozark Plateau, and the North-Central United States. Landscape vegetation fire models have been developed for nearly every region of the United States, including Alaska. However, these models vary greatly in design and in sensitivity to climate, terrain, and other parameters (Cary et al. 2006), and in general they are still being evaluated for use in predicting effects of changing climate on vegetation and fire. Many of these models are currently in use to support forest management decisions and the development of planning alternatives.

Other kinds of models combine current distribution of individual tree species based on data from the Forest Service Forest Inventory and Analysis program (FIA) with climate model outputs to project potential future distribution of suitable habitat for tree species (Iverson et al, in press, for the eastern US; Rehfeldt et al. 2006, for the western United States) or for bird species (Matthews et al. 2004 for the east). The outputs from such models have potential to help managers as they make decisions about appropriate approaches to reforestation under a changing climate.

Depending on the landscape model, the potential effects of fire, insects, other disturbance regimes, fuel treatments, or other management practices over time or at multiple scales can be evaluated. The interactions of disturbance (primarily fire in the western United States) with vegetation and climate can be incorporated into landscape models such as LANDIS, SIMMPLE, and MC-FIRE to compare effects under different management scenarios. Most of these models are currently operating at regional levels, and are not yet in nationwide application. Forest Service researchers are currently examining how best to incorporate climate change effects on tree growth into the Forest Vegetation Simulator (FVS), which is currently used by silviculturists and planners to simulate forest growth and dynamics, as well as responses to fire and fuel treatments and to insect and disease, at a stand level (http://www.fs.fed.us/fmsc/fvs/).

The large assortment of models mentioned above give scientists a wide range of important information to compare and evaluate. Models need to be tested at the local level and strengths and weaknesses sorted out. Cushman et al. (2006) discuss the future needs for improving the capabilities and utility of landscape models. Improved landscape models will enable us to better project and anticipate the potential effects of changing climate on vegetation and its interactions with fire and other disturbances such as insects and diseases. The resolution provided by these types of models provides essential information for site-specific planning and decisions.

The Interaction of Fire, Fire Behavior, and Climate Change

While current fire behavior modeling tools do not explicitly incorporate climate change, they all use data on weather and fuel condition to develop predictions. Thus fire behavior modeling tools can be used to evaluate multiple scenarios, such as the effects of extreme drought or higher temperatures that might be expected in a changing climate. Our knowledge of how fire behavior affects forests and rangelands comes from a combination of experimental studies (often using prescribed fire) and observations before, during and after wildfires. Such observations can occur at a range of scales from satellite remote sensing of fires and burned areas, to aircraft-based remote sensing or smoke sampling, to measurements of fluxes or changes in ecosystem properties made on the ground. Each year, seasonal severity projections include expected weather patterns over the fire season, including the known influences of changes in atmospheric circulation patterns, temperatures, and rainfall brought about by El Nino or La Nina, and other ocean oscillation patterns.

Good data on current and past fuel conditions as well as patterns of fire on the landscape provide a foundation to better understand the interactions between fire and climate. Ongoing monitoring is also essential. Two recent national projects being implemented under the auspices of the interagency Wildland Fire Leadership Council will help to provide this foundation. The LANDFIRE project (http://www.landfire.gov/index.php), a collaboration with the US Geological Survey and the Nature Conservancy, is mapping at the 15 meter resolution for fuels, vegetation, fire regime, condition class, terrain, and other important parameters. The Monitoring Trends in Burn Severity Project (http://svinetfc4.fs.fed.us/mtbs/) is mapping burn severity and perimeters for all large fires in the United States (over the past 20 years and into the future). Information from the burn severity project will eventually be integrated with LANDFIRE as part of the mechanism for updating LANDFIRE for fire and other disturbances. The two projects will provide essential baseline data layers which can be used for improved monitoring as well as modeling of changing fire regimes, effects of fuel treatments, fire behavior, fuel consumption and emissions, and potential interactions with climate.

Feedbacks between Fire and Climate Change

There is growing scientific concurrence that climate change will increase areas burned, which will result in increased emissions of carbon dioxide and other greenhouse gases from wildfires — both through increases in area burned and through increased emissions. Mitigation measures such as hazardous fuel reduction can help to reduce these effects (e.g. Johnson et al. 2007). Fire produces many emissions besides CO_2 (including methane, particulates, and other aerosols; Andreae and Merlet 2001). Some of these compounds are much more efficient at trapping radiation than CO_2 while others reflect heat and light. In addition, there are great variations among ecosystems in how fires affect the release of CO_2 from soil which normally stores about twice as much carbon as above ground parts of forests. In some systems, post-fire emissions from soil respiration are greatly reduced, while in others they may increase or remain relatively unchanged (Amiro et al.2003). Another factor that will affect the regional and perhaps global effects of fire on climate is the magnitude of the impacts of fire-induced vegetation changes on how the surface of the earth reflects or absorbs the sun's rays.

A number of recent papers have addressed this issue, but it is extremely complex, and current data are not adequate to evaluate the potential net affects. Smoke from wildfires can also cause severe local and regional air pollution. Smoke from large fires often travels great distances, and may affect local temperatures and air quality thousands of miles from its origin (e.g. Colarco et al. 2004, Damoah et al. 2004). While it is clear that increases in burn area and fire severity will increase greenhouse gas emissions, it is the balance among the influences of these various emission changes, the uptake of CO_2 by regrowing vegetation, the utilization of potential wildfire fuels for bioenergy or in wood products, and changes in vegetation composition, albedo and other factors that will determine the net effect of changing fire regimes on carbon storage and on climate.

Implications of Changing Fire Regimes for Carbon Storage

There is increasing attention being paid by scientists to the significant role that wildfire plays in the global carbon cycle (Schimel and Baker 2002). As long as the incidence and severity of wildfires remains constant, removal of carbon from the atmosphere through regrowth of vegetation in burned areas equals the wildfire carbon products emitted. An increase in wildfire will increase emissions of carbon gases and particulates and other greenhouse gases (IPCC 2007). Many forest management techniques, such as prescribed burning or thinning dense vegetation in appropriate fire regimes, can be used to make forests more resilient to wildfire, particularly in ecosystems typified by short intervals between fires or mixed severity fire regimes.

Research has shown that hazardous fuel reduction treatments in the appropriate type of fire regime are often effective at decreasing the severity of subsequent fires (e.g. Johnson et al. 2007). If the fuels that are removed are used either for bioenergy or in wood products, they are providing benefits in terms of overall carbon balance, either by offsetting use of fossil fuels or entering carbon into semi-permanent storage. Subsequent lower severity wildfires fires will emit less carbon to the atmosphere than would occur in untreated stands. Forest Service scientists are working with partners to develop better estimates of various components of the forest carbon cycle that include these alternate uses of materials (Smith et al. 2006) and account for the various processes involved as forests are harvested or burned, and as they regrow.

In the United States, the magnitude and effects of climate change, and its impact on fire regimes will vary in different regions of the country. We need to understand more about fuels, the effects of changing burn severity on carbon release, and how these effects will vary regionally.

I would like to turn to Dr. Bartuska for a discussion of science in support of managers and policymakers.

Science in Support of Managers and Policymakers

Scientists can assist managers and policymakers by providing knowledge and tools that support adaptive management in response to our changing climate. Adaptive management combines emerging research with evaluation of management practices. This enables managers to modify practices as our understanding of the science of these complex systems improves.

Research, such as that mentioned earlier, tells us that fire regimes are changing and will continue to change across North America, and that some of this change is due to changing climate, although measures such as fuel reduction can help to mitigate these effects. These changes may complicate fire management activities and suppression operations, alter ecosystem characteristics and increase potential fire risk and other losses to communities and infrastructure. We can also expect that new vegetation communities will develop over time as a reflection of the tolerances and adaptations of individual species.

Changes in vegetation and fire regimes will affect our ability to store carbon in forests and rangelands, and will affect atmospheric chemistry and climate. Scientists across the United States and around the world are developing new knowledge and new approaches to quantifying these impacts and improved methods of adaptation and mitigation to lessen the impacts of these changes.

There is good scientific basis for vegetation treatments in appropriate fire regimes to reduce wildfire severity; treatments will reduce stress and crowding of vegetation and increase resistance to severe drought and to bark insects. Because climate in many areas will change more rapidly than long-lived plant species can migrate, moderate to severe fires can be seen as opportunities to facilitate migration, either by planting a mix of species that may be better adapted to current and future climates, or by selecting seed from trees that grow in warmer seed zones or at lower elevations.

Because we can not predict precisely what species or genotypes will be best able to tolerate changing environments, managers may want to ensure a diverse mix of species on the landscape. Forest biomass from fuels reduction can be used for bioenergy and wood products – this will decrease the net effective emissions from wildfires, offset fossil fuel emissions, and help to increase carbon storage. Scientists are evaluating options for incorporation of organic matter from forest fuels into the soil, where it will decompose slowly, and not add to fire hazard as much as if left on the surface. While wildfire is a part of the problem of climate change and carbon storage, management of fire and fuels and thoughtful restoration of burned areas can be a part of the solution.

Conclusion

As we have presented, science can describe the connections between human and ecological systems. Scientists can help policymakers and managers evaluate options and interpret the effectiveness of potential management alternatives. Science can provide a solid foundation for the many non-scientific considerations that managers and policymakers must take into consideration. I hope the information we have provided has been helpful.

Mr. Chairman and members of the Committee, thank you for the opportunity to discuss the science of interactions of climate change and wildfire. Dr. Conard and I would be happy to answer any questions you might have.

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